Chapter 11
Final Disposal of Low-Level Radioactive Waste

11-1. General Considerations for Planning

a. Introduction. The final step in the process of cleanup of a site contaminated with radioactive wastes is its transport to and placement in an engineered site for final disposal. The only method currently practiced in the United States is direct shallow land burial, which is a form of permanent storage. Other types of storage methods are in use in other countries and are planned for the United States in the future. Although it is the final step in the cleanup process, engineering requirements or limitations on the form, volume, concentration or activity level, and packaging of the waste will affect many earlier decisions relative to treatment and handling. Therefore, consideration of the location and means of final disposal should begin very early in the planning stages of any cleanup project.

b. Onsite disposal. The first decision which must be addressed is whether to dispose of the waste onsite or offsite. Some DOE facilities have existing onsite disposal facilities. If an onsite disposal is available, and if the waste is suitable for disposal at the site, this is usually the preferred option. The use of an onsite disposal facility minimizes transportation impacts and costs, minimizes safety concerns, minimizes public exposure and concern, and simplifies contracting. All aspects of onsite disposal must meet EPA standards and, on DOE sites, the conditions of DOE orders relating to disposal.

c. New onsite facility. In many cases, an onsite disposal facility is not available. In these cases, the next choice is between creating a new onsite disposal area or using an offsite commercial facility. New osite disposal facilities have been constructed at some locations within the DOE complex to handle environmental restoration generated wastes. These include the sites of the uranium mill tailings remedial action (UMTRA) program and the former uranium processing facilities at Weldon Spring and Femald. Creation of a new disposal site is a very complex and lengthy legal, administrative, and engineering project. It is unlikely to prove efficient or economical unless there are very large volumes of waste to be disposed of. If preliminary analysis indicates that transportation and disposal costs for the expected volume and activity of wastes are expected to be very high, the creation of an onsite disposal facility should be considered. In this case, experts in this field should be retained. Planning and design of disposal areas is not described in this EM.

d. Offsite disposal. In most cases, the preferred choice will be disposal in an offsite commercial facility. Not all existing facilities are available because the Low Level Waste Policy Act set guidelines on accessibility (refer to Chapter 3 for a fuller explanation). Planners and engineers involved in radioactive waste cleanup activities should familiarize themselves with the requirements and costs for disposal at all probable sites at the earliest stage in the planning process, because these requirements will control many decisions regarding treatment and packaging. Reference to technical descriptions or advertising brochures is a logical first step in this process, but the facilities themselves should be contacted early in the process, because availability of capacity, activity levels, packaging and disposal requirements and costs can change at any time. In addition, new facilities may become available or existing ones may close. NRC regulations must be met for all aspects of transport to and disposal at commercial facilities.

11-2. Commercial Offsite Facilities

At the present time (December 1996), there are three commercial facilities open in the United States. In addition, several state compacts are planning new facilities, but none is expected to open before 1996. EM 1110-35-1 contains a description of the various state compacts. Brief descriptions of the three sites follow.

a. Richland, Washington.

(1) This site is on the Hanford Nuclear Reservation 25 miles northwest of Richland, WA. It is operated by American Ecology, Inc. (P.O. Box 638, Richland, WA 99352, telephone No. (509) 377-24 11). American Ecology subleases 100 acres (202 hectares) from the State of Washington, which leases 1,000 acres (2,023 hectares) from DOE. It began operating in 1965.

(2) Among the low-level radioactive wastes permitted to be disposed of at Richland are solid or solidified materials, contaminated equipment, cleaning wastes, tools, protective clothing, gloves, and laboratory wastes.

(3) The method of disposal is shallow land burial in trenches. The average trench is about 150 ft wide, 45 ft deep, and 800 ft long. Filled trenches are marked with permanent monuments, which describe the contents, boundaries, dates of use and other pertinent information.

All waste is packaged and shipped to the site for burial in accordance with DOT requirements. The containers of waste are then placed in excavated trenches that, when completely filled, are covered by at least 8 ft (2.4 m) of soil. Due to this depth, no additional protection is required for Class C waste. The trench is then topped with gravel to prevent wind erosion.

(4) The surface layers consist of deposits of sand and silt, with zones of gravel and cobbles. The underlying rocks consist of basaltic lavas. The closest aquifer is about 330 ft (100.6 m) below the surface of the site. The 330 ft (100.6 m) of soils overlying the closest aquifer are very dry. In fact, in this arid desert climate, the net flow of moisture in the soil beneath the site is actually toward the surface. The geology, arid climate, and burial techniques all contribute to the retention of the waste materials on the Richland site.

(5) Several locations on the site and in the surrounding area are tested on a regular basis by taking periodic air, soil, water and vegetation samples. The air quality is continuously monitored during site operations. These samples are then analyzed by an independent laboratory.

(6) In addition to the Richland site, U.S. Ecology also serves as the contractor to the Southwest compact and the Central States compact. They have been granted a license by the State of California, the host state for the Southwest compact. They have submitted a license application to the State of Nebraska, the host state for the Central States compact. In addition to their LLRW business, they also operate chemical waste disposal facilities in Nevada and Texas.

(7) The Richland site has been designated as the compact site for the Northwest compact area and, under a perpetual contract, serves as the disposal site for the Rocky Mountain Compact area, but they will accept no LLRW from other states. They do accept NORM from other states. Most of its waste comes from the Pacific Northwest. It is capable of disposing of larger quantities of waste than it currently receives.

b. Barnwell, South Carolina.

(1) This site is operated by Chem-Nuclear Systems, Inc. (P.O. Box 726, Barnwell, SC 29812, telephone No. (803) 259-1781). The site is about 300 acres and has operated since 1971. It is the current compact site for the Southeastern Regional Compact. It has served most generators east of the Mississippi River in the past. The South Carolina Legislature passed a bill in 1992 allowing it to remain open until January 1, 1996 for wastes from the Southeast compact and to accept wastes from outside of the Southeast compact until June 30, 1994. It is to be replaced by a new state compact site in Wake County, NC, but the licensing process has encountered delays.

(2) Only LLRW wastes in dry, solid form are accepted for disposal. Liquids, toxic chemicals, and high-level rad-inactive waste are not accepted. Class A waste may be packaged in steel drums or wood, carbon-epoxy, or high-integrity (polyethylene) containers. Class B waste is disposed of in polyethylene containers with concrete overpacks. Class C waste is disposed of in carbon-steel containers that are surrounded by concrete. These high-integrity containers are designed to maintain their integrity for 300 years in the trench environment and are sold by Chem-Nuclear.

(3) The Class A waste consists mostly of materials that have become radioactive as a result of being exposed to radioactivity, such as lab coats, gloves, shoe covers, tools, filters, and construction materials. Class B waste is generally dewatered ion exchange resins, and Class C waste is primarily induced-activity objects such as metal control rod blades.

(4) Ninety-five percent of the volume and 10 percent of the activity of the wastes disposed of at this site are Class A waste. Class B waste comprises 4 to 4.5 percent of the volume and 30 percent of the activity. Class C waste accounts for less than 1 percent of the volume but 60 percent of the activity. Cobalt-60 is the largest contributor to the activity for all three classes of waste.

(5) Class A waste is buried in a trench that is 1,000 ft long, 100 ft wide, and 17-20 ft deep. The trenches have a French drain system along one side that collects any moisture in the trench. Waste containers are stacked in the trench in an orderly manner. However, occasional random placements of loose lumber, pallets, etc., occur. Using a 3-D computerized grid system, each shipment's location and its contents are logged. For closure, the waste packages in each section of the trench are covered with loose sand for packing, and then a cap made of clay-rich material is packed over the trench and crowned to shed water. The same system is used for the disposal of Class B waste, except that the trench is only 30 ft wide. Class C waste is disposed of in trenches that are only 10 ft wide, and a remote-operated cable is used to pull the container out of the shipping cask and into the trench in order to protect the workers from radiation exposure. The entire Class C trench is covered with

reinforced concrete for closure in order to prevent future inadvertent entry.

(6) All rainwater is channeled from the bottom of the trenches to a pond, from which it infiltrates into the ground. It is tested for radioactivity and, if too much is found, the water is diverted into another pond for treatment.

(7) Approximately 900,000 ft^3 (25,489 m^3) of waste was disposed of in 1991, which is less than the 1.2 million ft^3 (33,985 m^3) the site can accept per year. The base charge for disposal (not including transportation) is $43/$ft^3$ ($15 18/$m^3$) of waste, with surcharges for weight, activity, cask load, high activity, and state and federal government inspection fees. Thus, volume reduction is very important to the generator. The average charge, including concentration and activity surcharges and special handling fees, is $200/$ft^3$ ($7,000/$m^3$), and the average charge for a container of Class C waste is $200,000.

c. Clive, Utah.

(1) This facility is in Tooele County, Utah, about 55 miles west of Salt Lake City and 3 miles south of 1-80 in the western Utah desert. It is operated by Envirocare of Utah, Inc. (215 South State St., Suite 1160, Salt Lake City, UT 84111, telephone No. (801) 532-1330).

(2) The Clive site began accepting NORM wastes in 1988, LLRW in 1991, and mixed wastes in 1993. It is the only commercial facility in the United States permitted to accept mixed wastes containing no more than Class A radioactive waste. It also accepts by-product, source, and special material, by-product 1 le(2) mill tailings, dried process sludges, CERCLA response action wastes, and treatment residues. It accepts no hazardous waste, except that which is a component of mixed waste.

(3) Materials may be shipped by either truck or rail. The Clive site has a proivate spur off the Union Pacific's main line. Materials may be shipped in a number of containers, including bulk transport in gondola railcars, intermodel containers, or dump trucks; or in metal boxes of various sizes, metal drums, or polyethylene bags.

(4) Unlike other sites, at Clive LLRW is placed and compacted in 12-in. lifts in a continuous cut-and-cover process. Thus, waste should not be compacted before shipping. The completed cell is entombed in a 7-ft clay radon barrier, a rock filter zone, and a coarse rock erosion barrier. There are three synthetic liners, each with a separate leachate collection system. Each customer's material is assigned a specific location within a cell. The material is then segregated and isolated to eliminate the potential for liability from another generator's waste.

11-3. Site Selection

a. Selection factors. The site to which the LLRW or mixed waste is to be shipped is based on several factors, including, but not limited to the following:

(1) Availability of a permitted site, which will accept wastes from the particular facility.

(2) Acceptability of the waste.

(3) Sampling and analysis requirements.

(4) Packaging requirements.

(5) Disposal costs.

(6) Transportation options.

(7) Transportation costs.

All of the above factors are affected by the volume, type, and activity of the LLRW wastes. Different options should be explored early in the planning process, with the final decision made only after detailed discussions with each facility about the factors listed above. For many facilities, only one disposal site may be available, because others may not accept wastes from areas outside their compact area.

b. Costs.

(1) Reliable and meaningful disposal cost data are difficult to obtain, because costs are dependent on many factors, including total volume, weight, activity level, type of packaging required, analysis fees, inspection fees, and transportation. Pricing policies of the different commercial disposal sites differ, and prices change from year to year. Sometimes volume discounts may be available. Some cost data are given in Section 11-2 b.(7) for order-of-magnitude estimating purposes only. Each situation is unique, so once all possible available disposal sites are identified, each site should be contacted and asked to quote prices for the specific types and volumes of wastes estimated to be present.

11-4. Planned Future Disposal Sites

a. Impending changes. The Northwest State Compact and the Rocky Mountain State Compact are planning to continue to use the Hanford disposal site for the foreseeable future. However, all other state compacts are planning to construct new facilities. None of the plans is far enough advanced to know the specific designs, but present indications are that none is planning to use nonengineered shallow land burial. Thus, it is certain that the general practice of LLRW disposal in the United States will change radically in the next few years. Many LLRW cleanup projects take several years to plan and implement. During that time, the status and availability of disposal sites and their rules and conditions for waste acceptance can change radically. Therefore, all engineers that are involved in LLRW projects should be aware of the current status of the applicable state compact facility and how its schedule and plans for construction and operations and rules for waste acceptance will affect their projects.

b. Other disposal options. Many different types of facilities have been proposed for LLRW disposal, both in the United States and in Europe and Asia. Some may be adopted in the United States in the future, so planners and engineers involved with LLRW disposal should be familiar with the basic concepts. However, the NRC has said in "Licensing of Alternative Methods of Disposal of Low-Level Radioactive Waste" (NRC 1986) that for the present it will focus on cementitious materials with earthen covers and will expend minimal resources on aboveground vaults or mined cavities.

(1) Deep shaft mine. Germany is planning to bury LLRW in an abandoned iron mine near Braunschweig (the Konrad mine). The mine is over a mile deep and was selected because its unusual geological situation makes it very dry. The waste would be placed in special containers in concrete chambers in the mine and backfilled with a special porous cement mixture which will allow for escape and dissipation of the gas that will be produced. Wastes which can be incinerated will be required to be, and the ashes will be required to be placed in special containers.

(2) Shallow mined cavities.

(a) Because of the difficulty of finding suitable deep geological strata and the cost of constructing and operating new deep mines, some have proposed shallower mines, usually above the water table, in stable geological strata. Sweden has adopted a version of this approach. The excavated disposal facility is 60 m deep in granite, but, instead of being above the water table, is under the floor of the Baltic Sea, about 200 m offshore near the village of Forsmark, about 100 km north of Stockholm. The facility contains four underground vaults and a silo.

(b) Each vault was created to hold a specific form of waste, and the highest-level waste is put in the silo. Low-level wastes are handled with no shielding, because they are not considered very harmful. Intermediate-level waste is handled either remotely or by a special, shielded forklift.

(c) All wastes are treated by the generators. The wastes can be in concrete or steel boxes or steel drums. The containers have to be of a type approved by the regulatory authorities. Concrete boxes are used for medium-level ion exchange resins, filter materials, and metal scrap or trash. Cement grout is used for solidification in the concrete boxes. Steel drums or boxes are used for the same type of waste, but the solidification material can be concrete or bitumen, and, since the shielding capacity of the steel is not as high as concrete, they are usually used for low-level waste. No wastes are required to be incinerated, but, if they are, the ashes are placed in a 200-ℓ steel drum. This drum is placed in a larger drum, and the void is filled with grout. Concrete tanks are used for dewatered low-level ion exchange resins. The tank is lined with a rubber sack, and no solidification matrix is used. The average cost, including the packages, for disposal at the SFR is \$4600/m^3 in 1992 dollars.

(d) Forsmark is considered an appropriate place for a radioactive waste repositorybecause the rock is of good quality, the groundwater head is very low, and, with its location under the sea, no one would be drilling for drinking water at least until the seabed rises above the water, which has been predicted to be in 1,000 years. After the facility is sealed, drainage pumping will cease, and the repository will fill with water. Thus, the barriers are constructed to prevent the movement of the groundwater out of the repository.

(3) Earth-mounded concrete bunker.

(a) A somewhat simpler and cheaper option than the deep or shallow mined cavities is the above-ground concrete bunkers, covered with earth. This technology is practiced in France and is being planned for adoption by all of the state compacts in the United States. Thus, any engineers involved in projects expected to be active past 1996 should be familiar with it.

(b) The new French disposal facility is the Centre de l'Aube, which was built to replace the Centre de la Manche, which has been in operation since 1969 and is almost full. Both facilities use the monolith technique. However, the Centre de l'Aube design is quite different from, and improves upon, the Centre de la Manche design.

(c) At Centre de l'Aube, the waste is shipped primarily by train to the nearest station and then brought by truck to the site. At the security checkpoint, the shipping manifest is checked against the cargo, and random packages are opened and checked for conformity to ANDRA (the French Waste Disposal Agency) treatment and immobilization specifications.

(d) No liquid waste is accepted at the Centre, and ANDRA has developed waste acceptance criteria that the operators must follow. The Centre has an onsite compaction and grouting facility that is used to immobilize waste when needed.

(e) The waste is then taken by truck to one of the monoliths, or disposal units. The monoliths are above--ground, concrete vaults made of 0.3-m (l-ft) thick reinforced concrete with an underground drainage system. The waste packages are removed from the truck by a manually operated overhead crane. The crane then becomes automatically controlled, and the packages are placed in the vault automatically to reduce the exposure of the crane operator and to place the containers more accurately with a 10-cm space between them. The structure is protected from rain by a movable rail-mounted building that covers the section being filled and contains the crane and crane operator.

(f) After each layer of containers is in place, it is covered with grout (between the containers and 10 cm over their tops), and, when the structure is completely filled with six layers, a concrete roof 1 m thick is poured. Then, the entire structure is sprayed with a waterproof plastic covering.

(g) When a row of four monoliths is filled and sealed, the spaces between and over the monoliths are filled with earth. A final cover composed of layers of bitumen, sand, clay, and topsoil is placed over the row. The cover is peaked in places to facilitate runoff to a surface drainage system. After closure, the site will have the appearance of a series of hills and will be landscaped to blend with the surrounding forest.

(h) The French consider this a three-barrier system (waste container, concrete vault, and top cover). Since they do consider the waste container a radiation barrier, a detailed set of specifications for each given waste form has been developed and must be followed by the generators for their waste to be accepted at Centre de l'Aube. However, there are no requirements that address the chemical composition of the waste. ANDRA does not accept responsibility for the waste until it has cleared the security checkpoint.

(i) A computerized tracking system is used at the Centre. Each container displays a sticker with a bar code that is read by a scanner during the automated placement stage. This information is stored along with the container's position in the monolith and all of the information about the container's contents. This information can be accessed by ANDRA, the Centre, or the generator who is also online.

(j) The Centre de l'Aube will operate for 30 years, until approximately 2020, but institutional control of the area will remain with ANDRA for 300 years. At that time, the area will be allowed to be used for any purpose.

(k) The development costs for Centre de l'Aube were approximately $240 million (1.2 billion francs) including design. The cost for waste disposal is $1 ,600/$m^3$, or 8,000 francs/$m^3$, and there are no surcharges except for waste that must be treated at the site.